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Effects of Extractives on Specific Gravity of Southwestern Ponderosa Pine

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Specific gravity is the simplest and most useful single index to the suitability of wood for many uses. In resinous species, however, the presence of extractives results in a higher specific gravity than warranted by cell wall substance alone, introducing a systematic error into estimated strength characteristics and pulp yields. The results of this study indicate that mean specific gravity of southwestern ponderosa pine is reduced approximately 12 percent (0.421 to 0.371) by the removal of alcohol-, benzene-, and water-soluble extractives. Extracted specific gravity can be estimated from measures of unextracted specific gravity by the equation Y (Ext. Sp. Gr.) = 0.593 - 0.092 / X (Unext. Sp. Gr.). Quantity of extractives was the only measured tree characteristic found to contribute significantly to variation in unextracted specific gravity.

KEY WORDS: *Pinus ponderosa*, density, extracts.

Specific gravity is a useful index to the suitability of wood for many uses. Specific gravity largely determines yields of such products as pulp and charcoal, and is closely correlated with mechanical strength. It also provides some idea of the working properties and finishing characteristics of wood.

The specific gravity of wood cell wall substance has been found relatively constant at 1.53 regardless of species (McKimmey 1959, Mitchell 1965). Since wood is a cellular material, however, specific gravity may vary among species and trees within a species group. Variation is due to differences in proportion of the wood made up of cell walls and included infiltrates or extractives.

The presence of extractive components may increase both magnitude and variability of specific gravity for resinous species such as ponderosa pine (Pinus ponderosa Laws.) (Paul 1955, U.S. Forest Serv. 1965a, Voorhies 1969). Since strength characteristics and pulp yields are a function of cell wall substance only, estimates based on "unextracted" specific gravity may be somewhat high.

The Study

The study was designed to determine specific gravity variation in a range of ponderosa pine forest density conditions, age and size class intermixtures, and volume distributions common to Arizona. Specific objectives were to: (1) determine specific gravity of unextracted sample material; (2) determine specific gravity of the same sample material after removal of all alcohol-, benzene-, and water-soluble extrac-

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tives; (3) describe the effect of included extractives upon the magnitude of unextracted specific gravity; and (4) investigate the association between specific gravity values and commonly employed measures of tree and stand characteristics.

Specific gravity was determined from increment cores taken at breast height (4.5 feet); consequently, all values are indicative of specific gravity at breast height rather than for the tree as a whole. For most conifers, however, unextracted specific gravity decreases only slightly with increase in height (U.S. Forest Serv. 1965b, Wahlgren and Fassnacht 1959).

Field Procedures

Full-length increment cores were collected from 442 ponderosa pine trees as part of a timber quality inventory of three experimental areas in Arizona: the Beaver Creek watersheds, the Long Valley Experimental Forest, and the West Fork Castle Creek watershed. Inventory procedures were based on point sampling techniques, with an increment core taken from one tree at each sample point. Supplementary data describing tree and stand characteristics were available from the inventory.

The sample areas represent a broad range of ponderosa pine site quality. The Beaver Creek watersheds, 45 miles south of Flagstaff, contain lower quality cutover stands, with an estimated site index (Meyer 1961) of 45 to 60 feet at 100 years. The Long Valley Experimental Forest, 65 miles southeast of Flagstaff, represents the better timber-growing sites, with a site index of 85 to 90 feet, and at the time of sampling was one of the few remaining stands of virgin ponderosa pine in Arizona. The West Fork Castle Creek watershed, 12 miles southwest of Alpine, is considered a good timber-growing area, with a site index range of 65 to 80 feet.

Laboratory Procedures

Unextracted specific gravity (green volume-ovendry weight) was determined for each increment core by the weight-volume method (U.S. Forest Serv. 1956). Green volume was obtained by submerging single cores in a container of water and measuring the displacement. The cores were then ovendried at 105° C, weighed, and specific gravity calculated.

To remove soluble extractives, the increment cores were placed in a Soxhlet extractor (fig. 1). A solvent solution of one-third ethyl

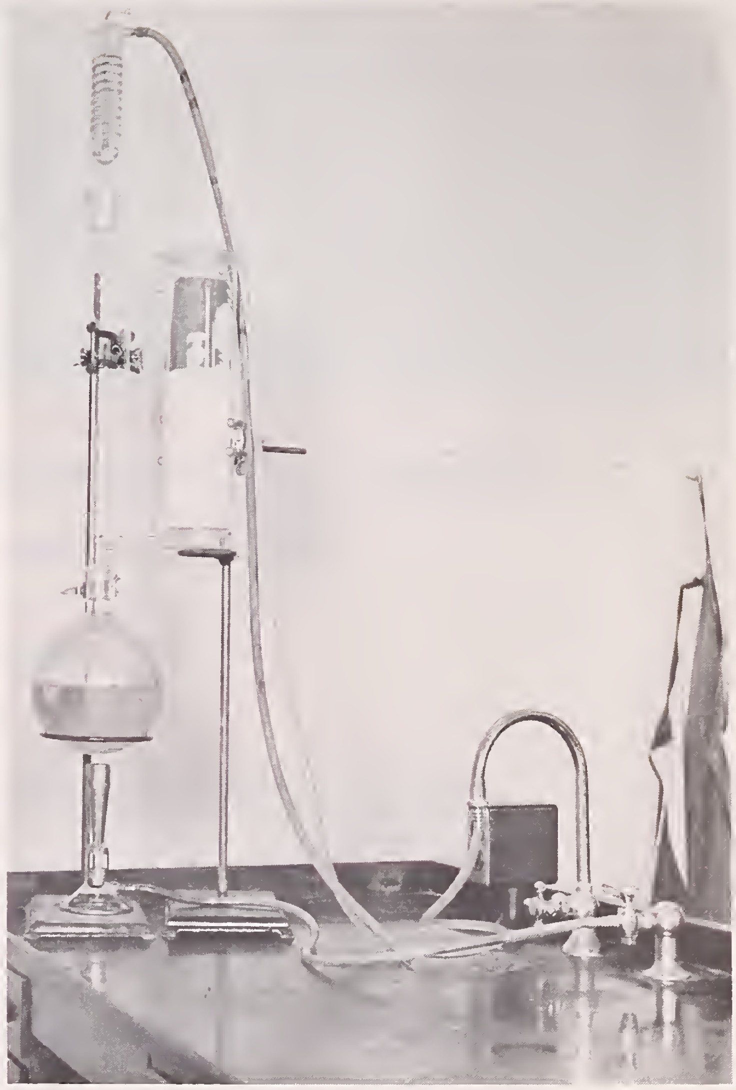

Figure 1.--A modified Soxhlet extractor, provided by the School of Forestry, Northern Arizona University, was used to perform the extractions.

alcohol and two-thirds benzene was refluxed over the cores for 24 hours.[2] The cores were then removed from the extractor and submerged in boiling distilled water for 4 hours to remove water soluble extractives.

Extracted increment cores were saturated with water under vacuum, and their specific gravity determined by the maximum moisture content method (Smith 1954). The cores were then ovendried at 105° C , weighed, and their specific gravity was again computed by the weight-volume method. Values obtained by the maximum moisture content method served as a check on values determined by the weight-volume method, which were used in subsequent analysis.

[2]Cores extracted according to procedures developed by Professor Glenn Voorhies, School of Forestry, Northern Arizona University, Flagstaff, and with extraction equipment provided by the School of Forestry.

Analysis and Results

Preliminary analysis of specific gravity data indicated no significant differences among areas; consequently, data were combined in all analyses. Specific gravity values for the total sample were:

	Minimum	Mean	Maximum
Prior to extraction	0.308	0.421	0.621
Following extraction	.283	.371	.500

These values agree with values of 0.416 (unextracted) and 0.374 (extracted) reported for young-growth ponderosa pine site trees by Voorhies (1969).

Although extraction reduced the range of variation in specific gravity, relative variation among sample cores did not change significantly. Coefficients of variation before and after extraction were 11.8 and 9.5 percent, respectively.

In using specific gravity as an index of wood quality or product yield, it is frequently desirable to estimate extracted specific gravity (or quantity of extractives) from unextracted specific gravity. To develop a basis for such estimates, regressions were calculated relating extracted specific gravity and quantity of extractives to unextracted specific gravity (fig. 2).

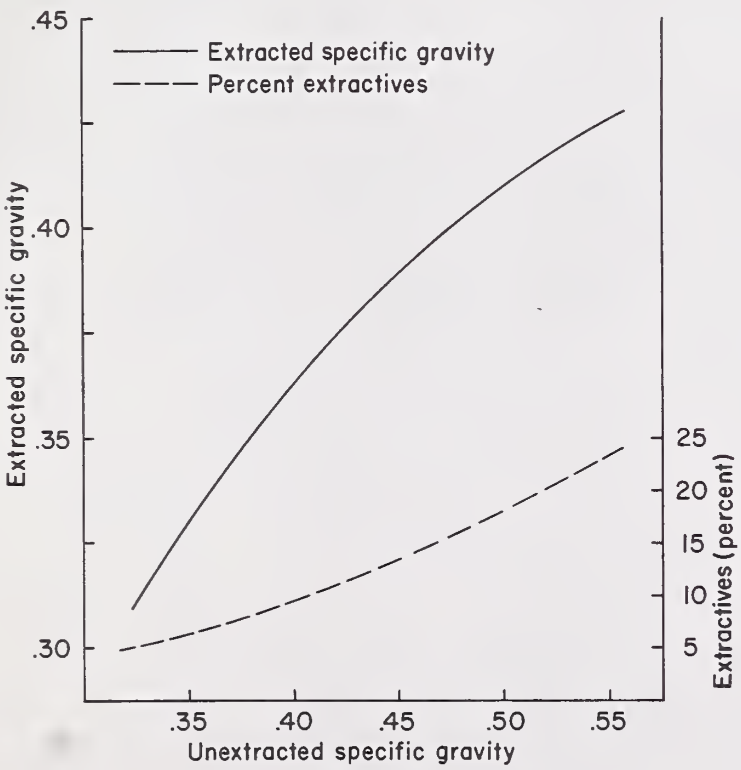

Figure 2.--Unextracted specific gravity provides a basis for estimating extracted specific gravity and quantity of extractives, important in predicting wood quality and fiber product yields.

The empirical equations describing these relationships are:

$$\hat{Y} = 0.593 - 0.092/X \quad (r^2 = 0.50) \tag{1}$$

where

$\hat{Y}$ = predicted extracted specific gravity
X = unextracted specific gravity

$$\hat{Y} = -73.320 + 10.615/X + 140.504X \quad (r^2 = 0.35) \tag{2}$$

where

$\hat{Y}$ = predicted percent extractives
X = unextracted specific gravity.

These equations can be used with unextracted specific gravity values to estimate quantities of extractives soluble in alcohol, benzene, and water, and to reduce error in estimating such characteristics as wood strength and pulp yields.

Possible correlations between specific gravity and measured tree and stand characteristics were tested. Six characterisitics, reported to be correlated with specific gravity elsewhere (McKimmey 1959, Mitchell 1965, Paul 1963, Thor 1964), were analyzed:

1. Diameter breast high (inches).
2. Tree volume (cubic feet computed as vol. = $0.00545fD^2H$, where form factor (f) = 0.42).
3. Age at breast height (expressed as the reciprocal, 1/age).
4. Quantity of extractives (percent, as measured in core extractions).
5. Growth rate (expressed as dia./age).
6. Forest density (expressed as number of trees tallied at sample point with an angle gage corresponding to BAF=25).

Of these, only the first four were significantly related to one or both measures of specific gravity (table 1), and the only reasonably strong association was between percent extractives and unextracted specific gravity. Combining independent variables in multiple regression fashion did not significantly improve the correlations.

Conclusions

1. The mean specific gravity of ponderosa pine is reduced approximately 12 percent (0.421 to 0.371) by the removal of alcohol-, benzene-, and water-soluble extractives.
2. Empirical equations can be used to estimate extracted specific gravity from measures of unextracted specific gravity, thereby improv-

Table 1.--Correlations between specific gravity and independent variables significantly related to one or both measures of specific gravity[1]

Independent variable	Range of sample			Coefficient of determination related to --	
	Minimum	Mean	Maximum	Unextracted specific gravity	Extracted specific gravity
Diameter breast high (inches)	3.1	15.9	52.9	ns	0.03
Tree volume (cubic feet)	1.2	64.2	500.0	ns	.02
Reciprocal of age (1/years)	.003	.015	.053	-0.03	-.04
Quantity of extractives (percent)	0.3	11.4	39.4	.35	.03

[1] Significance judged at the $\alpha = 0.05$ level.

ing estimates of such characteristics as wood strength and pulp yields.

3. Correlations between commonly measured tree and stand characteristics and specific gravity are weak, and of no practical value in identifying causes of variation in specific gravity.

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